

EXPERIMENTAL AND PETROLOGICAL INVESTIGATIONS INTO THE ORIGIN OF THE LUNAR CHANG'E 5 BASALTS. C. P. Haupt¹, C. J. Renggli¹, M. Klaver¹, E. S. Steenstra¹, J. Berndt¹, A. Rohrbach¹, and S. Klemme¹, ¹Institut für Mineralogie, Universität Münster, Germany. (chaupt1@uni-muenster.de)

Introduction: The latest returned lunar samples from the China National Space Administration's Chang'e 5 (CE5) mission comprise basalt samples of the previously unsampled northern Oceanus Procellarum region [1]. First geochemical studies of these basalts agree with crater counting chronologies on their very young (~1.9 Ga) age [2], but their origin remains highly debated. To explain young volcanism on the Moon, different heat sources have been debated, including KREEP (K-REE-Phosphorous) or volatile element enrichment in the source [3], an insulating megaregolith layer, or crustal thinning and decompression melting [4]. However, geochemical investigations of the samples revealed an absence of a KREEP-isotopic signature [4] and negligible water and volatile contents [5]. The CE5 samples are hence a unique chance to study alternative explanations for the occurrence of volcanic activity late in lunar history.

To further our understanding of the petrogenesis of the CE5 basalts, we conducted high-P high-T phase equilibria experiments to examine whether these samples could be melts of the lunar mantle [6]. Additionally, we construct a fractional crystallization model to evaluate, if CE5 basalts could be products of extensive fractionation [1, 4].

Experimental Methods:

Starting materials. We synthesized two experimental starting materials based on two CE5 basalt compositions [2] using reagent grade oxides (SiO₂, TiO₂, Al₂O₃, Fe₂O₃, Cr₂O₃, MgO) and carbonates (CaCO₃, MnCO₃, Na₂CO₃, K₂CO₃). The mixtures were decarbonated at 1000 °C and subsequently homogenized under ethanol in an agate mortar. The resulting mixture was then reduced at 1100 °C in a graphite crucible under CO atmosphere. The final starting material was reground and mixed under acetone and stored in a desiccator.

High-Pressure experiments. Piston-cylinder experiments were conducted in the high-pressure lab at Universität Münster (Germany) using talc-pyrex as a pressure medium and graphite-lined Pt capsules to control the fO_2 of the dry assembly to IW+1.5 [7]. Experimental conditions ranged between 1–2.5 GPa and 1100–1250 °C. Run durations were between 6–17 hours. After rapid quench, run products were mounted in epoxy resin and polished with diamond pastes for microbeam analyses.

Modelling a possible source composition: To investigate if CE5 basalts could be the product of

fractional crystallization of primitive lunar mantle melts, we need to constrain a parental melt. During the Apollo missions several primitive melt candidates with high Mg# (0.47–0.67) were sampled. We modeled the liquid evolution of known primitive lunar mantle compositions (e.g., A14 green, A14/A15/A17 yellow, A17 orange, A15 red glass [8]) upon fractional crystallization of the melt. The evolution of a potential source liquid composition by fractionation is calculated for the major element oxides. First, equilibrium olivine was incrementally removed from the melt following the approach of [9] with a suitable Fe/Mg K_D [10]. Fractional crystallization of plagioclase, ilmenite and armalcolite, orthopyroxene and clinopyroxene were also considered.

Results and Discussion:

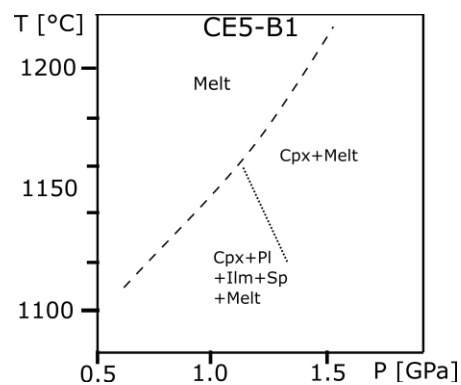


Figure 1: Stability fields of minerals and melt in high-P high-T experiments. Cpx = clinopyroxene, Ilm = ilmenite, Sp = chromite-ulvöspinel

A point of multiple phase saturation (MSP: 1.2 GPa and 1150 °C) can be inferred from the high-P phase relations of one analyzed basalt composition (Figure 1). Hence, CE5 basalts are likely primary melts from a mantle composed of the phases present at MSP, i.e. clinopyroxene, plagioclase and Fe-Ti oxides (ilmenite and ulvöspinel, Figure 1). In this case, the MSP P-T conditions represent minimum conditions of origin prior to eruption [11]. The present phases at MSP are uncommon for lunar primitive mantle, which typically consists of olivine, orthopyroxene, and spinel at the MSP [11]. The assemblage found at MSP resembles a late cumulate of the crystallizing fractional sequence of the cooling lunar magma ocean [12]. These so-called Iron-bearing cumulates (IBC), which are estimated to

form at 70–100 km depth, are denser than the underlying harzburgitic mantle and due to this density-contrast the lunar mantle might have “turned-over” [12]. Thus, IBCs may have migrated to ~260 km [13], could have settled and melted there during thermal equilibration. The constraints of the overturn remain, nonetheless, matter of debate.

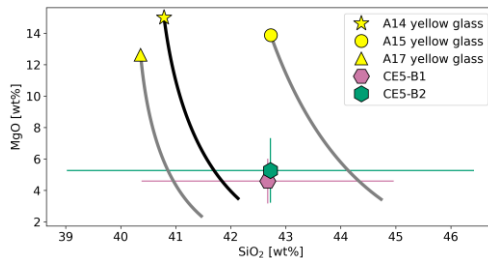


Figure 2: Apollo 14, 15 and 17 yellow glass compositions in yellow [7]. Grey and black lines represent liquid evolution upon olivine removal in 1 % steps. Hexagons are CE5 basalt compositions and errors as reported in [2]

Our fractional crystallization model offers an alternative explanation for the origin of the CE5 basalts, showing that extensive fractionation of olivine from a parental lunar melt composition similar to known Apollo glass compositions leads to a liquid composition very similar to the CE5 basalts (Figure 2).

Considering the heat distribution in the lunar mantle at the time of the CE5 basalts’ eruption, we find that the aforementioned two possible origins require different temperatures in the lunar mantle: For the hypothesis of the basalts being primary melts of a mantle cumulate, the required T in the lunar mantle at 2 Ga would be between 1100–1200 °C, which is far higher than lunar mantle temperatures predicted by symmetric thermal evolution models, even if a so-called megaregolith layer is considered [14]. However, an asymmetric chemical structure of the lunar mantle with heat-producing elements concentrated in the mantle beneath the Procellarum KREEP terrain may predict elevated heat in that area [15]. This asymmetry could be induced by e.g., a large impact (such as the South-Pole Aitken impact [16]) which may have caused thermochemical instabilities pushing lunar mantle cumulates and KREEP towards the lunar nearside.

An extensive fractionation of a parental melt of A14 yellow glass composition requires an even hotter lunar mantle at the time of CE5 eruption (~1530 °C at 500 km depth [17]) which deems the second hypothesis less likely.

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